

CLAIMS

We claim:

1. A catalyst comprising a porous metal support, a buffer layer, an
5 interfacial layer, and a catalytically active layer on the surface; wherein the porous
metal support has an average pore size of from 1 μm to 1000 μm ; wherein the
porous metal support is selected from the group consisting of honeycomb, foam, felt,
and wad;

wherein the buffer layer is disposed between the porous support and the
10 interfacial layer, and the interfacial layer is disposed between the catalytically active
layer and the buffer layer;

and wherein the buffer layer comprises a metal oxide.

2. A catalyst comprising a porous metal support, a buffer layer, and an
15 interfacial layer;

wherein the porous metal support has an average pore size of from 1 μm to
1000 μm ; wherein the porous metal support is selected from the group consisting of
honeycomb, foam, felt, and wad; wherein the buffer layer is disposed between the
porous support and the interfacial layer; and wherein the catalyst possesses thermal
20 cycling stability such that, if exposed to 3 thermal cycles in air, the catalyst exhibits
less than 2% flaking;

and wherein the buffer layer comprises a metal oxide.

3. The catalyst of claim 2 wherein the catalyst possesses oxidation
25 resistance such that, if it is heated at 580°C in air for 2500 minutes the catalyst
increases in weight by less than 5%.

4. A method of making a catalyst comprising the steps of:
selecting a porous support selected from the group consisting of honeycomb,
30 foam, felt, and wad;

vapor depositing a buffer layer on said porous support;

wherein the buffer layer comprises Al_2O_3 , TiO_2 , SiO_2 , and ZrO_2 or combinations thereof; and
depositing an interfacial layer on said buffer layer.

5 5. A process of converting at least one reactant to at least one product comprising:

passing at least one reactant into a reaction chamber;
wherein said reaction chamber comprises the catalyst of claim 1;
conversion of said at least one reactant into at least one product; and
10 passage of the product out of the reaction chamber.

6. The catalytic process of claim 4 wherein said process is selected from the group consisting of: acetylation, addition reactions, alkylation, dealkylation, hydrodealkylation, reductive alkylation, amination, aromatization, arylation,
15 autothermal reforming, carbonylation, decarbonylation, reductive carbonylation, carboxylation, reductive carboxylation, reductive coupling, condensation, cracking, hydrocracking, cyclization, cyclooligomerization, dehalogenation, dimerization, epoxidation, esterification, exchange, Fischer-Tropsch, halogenation, hydrohalogenation, homologation, hydration, dehydration, hydrogenation,
20 dehydrogenation, hydrocarboxylation, hydroformylation, hydrogenolysis, hydrometallation, hydrosilation, hydrolysis, hydrotreating, hydrodesulfurization/hydrodenitrogenation (HDS/HDN), isomerization, methanol synthesis, methylation, demethylation, metathesis, nitration, oxidation, partial oxidation, polymerization, reduction, steam and carbon dioxide reforming,
25 sulfonation, telomerization, transesterification, trimerization, water gas shift (WGS), and reverse water gas shift (RWGS).

7. The catalytic process of claim 5 wherein said process is selected from the group consisting of: acetylation, addition reactions, alkylation, dealkylation,
30 hydrodealkylation, reductive alkylation, amination, aromatization, arylation, autothermal reforming, carbonylation, decarbonylation, reductive carbonylation,

carboxylation, reductive carboxylation, reductive coupling, condensation, cracking, hydrocracking, cyclization, cyclooligomerization, dehalogenation, dimerization, epoxidation, esterification, exchange, Fischer-Tropsch, halogenation, hydrohalogenation, homologation, hydration, dehydration, hydrogenation, dehydrogenation, hydrocarboxylation, hydroformylation, hydrogenolysis, hydrometallation, hydrosilation, hydrolysis, hydrotreating, hydrodesulfurization/hydrodenitrogenation (HDS/HDN), isomerization, methanol synthesis, methylation, demethylation, metathesis, nitration, oxidation, partial oxidation, polymerization, reduction, steam and carbon dioxide reforming, sulfonation, telomerization, transesterification, trimerization, water gas shift (WGS), and reverse water gas shift (RWGS).

8. Microchannel apparatus in which at one of the interior walls of the apparatus have been coated with a buffer layer comprising a metal oxide, wherein the buffer layer has a thickness of between $0.05\text{ }\mu\text{m}$ and $10\text{ }\mu\text{m}$.

9. The microchannel apparatus of claim 8 further comprising an interfacial layer disposed on the buffer layer.

10. The microchannel apparatus of claim 8 wherein the buffer layer has been vapor deposited.

11. The microchannel apparatus of claim 9, wherein said walls comprise at least one wall of the reaction chamber and further comprising a catalytically active material disposed on the interfacial layer.

12. The method of claim 4 wherein said buffer layer is titania.

13. The catalyst of claim 1 wherein the catalyst possesses thermal cycling stability such that, if exposed to 3 thermal cycles in air, the catalyst exhibits less than 2% flaking.

14. The catalyst of claim 1 wherein the catalyst possesses oxidation resistance such that, if it is heated at 580°C in air for 2500 minutes the catalyst increases in weight by less than 5%.

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15. The process of claim 5 wherein said reaction chamber has walls and at least one of said walls has disposed thereon:

a buffer layer;

an interfacial layer; and

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a catalytically active layer.

16. The catalyst of claim 1 wherein the catalyst possesses oxidation resistance such that, if it is heated at 750°C in air for 1500 minutes, the catalyst increases in weight by less than 0.5%.

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17. The catalyst of claim 1 wherein the porous support is a metal and the catalytically active layer is distributed on surfaces throughout catalyst such that reactants passing through the catalyst can react anywhere along the passage through the catalyst.

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18. The catalyst of claim 1 wherein said buffer layer is nonporous.

19. The catalyst of claim 3 wherein the buffer layer is between 0.05 and 10 μm thick.

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20. The catalyst of claim 1 wherein the interfacial layer has a BET surface area of at least 1 m^2/g .

21. The catalyst of claim 2 wherein the catalyst is a monolith having a width of 0.1 mm to about 2 cm and a thickness of less than 1 cm.

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22. The process of claim 4 wherein a catalytically active material is simultaneously deposited with the interfacial layer.

23. The method of claim 4 wherein the interfacial layer is deposited from
5 solution.

24. The method of claim 4 wherein the step of vapor depositing comprises chemical vapor depositing.

10 25. The method of claim 4 wherein the step of vapor depositing a buffer layer comprises the steps of: vapor depositing a TiO₂ layer; and vapor depositing a dense alumina layer over the TiO₂ layer; and wherein the step of depositing an interfacial layer comprises depositing a less dense, high surface area alumina layer over the dense alumina layer.

15 26. The method of claim 4 wherein the porous support comprises a metal foam and the catalyst has a surface area of greater than 2.0 g per cubic centimeter.

20 27. The method of claim 4 wherein the porous support comprises a metal foam and the metal foam is etched prior to vapor depositing the buffer layer.

25 28. The method of claim 24 wherein the support comprises a metal foam and wherein the chemical vapor deposition is conducted in a temperature range of 250 to 800 °C.

29. The method of claim 24 wherein a precursor for the chemical vapor deposition is selected from the group consisting of: organometallic compounds, halides, carbonyls, acetonates, and acetates.

30 30. The method of claim 4, wherein the support comprises a structure selected from the group consisting of honeycomb, foam, felt, and wad; and the

catalyst possesses oxidation resistance such that, if it heated at 750 °C in air for 1500 minutes the catalyst increases in weight by less than 0.5%.

31. The catalyst of claim 1 wherein the interfacial layer comprises a
5 material selected from the group consisting of nitrides, carbides, sulfides, halides and carbon.

32. The catalyst of claim 1 having oxidation resistance such that, if it is
heated at 750 °C in air for 1500 minutes the catalyst increases in weight by less than
10 0.5%.

33. The method of claim 4 wherein the porous support has a porosity in the range of 70 to 98%.

15 34. The catalyst of claim 2 wherein the porous support has a porosity in the range of 70 to 98%.

35. The catalyst of claim 1 wherein the porous support comprises a foam, felt, wad or combination thereof.
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36. The catalyst of claim 2 wherein the porous support comprises a foam, felt, wad or combination thereof.

37. The method of claim 4 wherein the porous support comprises a foam, felt, wad, or combination thereof.
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38. The method of claim 37 wherein the step of vapor depositing comprises chemical vapor depositing.

30 39. The catalyst of claim 1 wherein the porous metal support has an average pore size of from 1 to 500 µm.

40. The catalyst of claim 2 wherein the porous metal support has an average pore size of from 1 to 500 μm .

5 41. The catalyst of claim 1 wherein the interfacial layer has a thickness that ranges from 1 to 50 μm .

42. The catalyst of claim 2 wherein the interfacial layer has a thickness that ranges from 1 to 50 μm .

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43. The catalyst of claim 1 wherein the interfacial layer comprises a material selected from the group consisting of nitrides, carbides, sulfides, halides and carbon.

15 44. The catalyst of claim 2 wherein the porous metal support comprises a foam, felt, wad or combination thereof.

45. The method of claim 4 wherein the porous support is a porous metal support and a catalytically active material is simultaneously deposited with the
20 interfacial layer.

46. A method of making microchannel apparatus comprising vapor depositing a buffer layer on at least one interior wall of a microchannel apparatus.

25 47. A microchannel apparatus made by the method of claim 46 wherein the buffer layer comprises a metal oxide.

48. The method of claim 47 wherein the buffer layer has a thickness of between 0.05 μm and 10 μm .

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